Early Development of the Muskellunge, *Esox masquinongy*, of Stony Lake, Ontario.

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by

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ABSTRACT

Development of muskellunge, Esox masquinongy, reared at the Deer Lake Hatchery (Ontario Ministry of Natural Resources) in 1981 and 1982, was studied. Fertilized eggs (preserved mean diameter = 2.9 mm) of muskellunge hatched after 193 degree-days (in 1981), and newly hatched larvae ranged from 7.8 to 8.9 mm total length (TL), mean = 8.6 mm. The head was deflected over a large, amber yolk sac. Pectoral buds were present. Eyes were lightly pigmented; a band of melanophores extended hypaxially from the head to the caudal region. At 14 to 15 mm TL, larvae were elongate of body and snout, had teeth, and sixty-six myomeres. First exogenous feeding occurred at about 14.5 mm, when the swim bladder inflated. The full complement of fin rays occurred in 29.1 mm larvae and the fin fold disappeared at 41 mm TL. First squamation appeared at 53 mm TL. Early juveniles were pigmented laterally with indistinct vertical bars and vermiculations; the lateral line, dorsal mid-line, and venter were essentially unpigmented.

RÉSUMÉ

En 1981 et 1982, nous avons étudié le développement de maskinongés (Esox masquinongy) élevés à la station de pisciculture Deer Lake (Ministère des Richesses naturelles de l'Ontario). Les oeufs fécondés (diam. moyen de 2,9 mm, d'après des échantillons en conservation) ont éclos lorsqu'il s'était accumulé 193 degrés-jours (1981); la longueur totale (LT) des larves à l'éclosion variait de 7,8 à 8,9 mm avec une moyenne de 8,6 mm. La tête de la larve se recourbe sur un volumineux sac vitellin de couleur ambrée. Les nageoires pectorales sont à l'état de bourgeons. Les yeux sont légèrment pigmentés et une bande de mélanophores hypo-axiale parcourt le corps, de la tête jusqu'à la région caudale. Les larves de 14 ou 15 mm de LT avaient le corps et le museau allongés; elles avaient des dents et l'on a dénombré 66 myomères. Elles ont commencé à absorber de la nourriture lorsqu'elles mesuraient environ 14,5 mm, lorsque la vessie gazeuse s'est gonflée. Les rayons de nageoires étaient tous formés à 29,1 mm et le repli des nageoires est disparu a 41 mm. Les premières écailles sont apparues à 53 mm. Au déhut de la phase juvénile, les poissons présentaient une pigmentation latérale en plus de rayures verticales et de vermiculations indistinctes; la ligne latérale, la ligne médiane du dos et le ventre étaient essentiellement dépourvus de pigmentation.

INTRODUCTION

A native of northeastern North America, the muskellunge, Esox masquinongy, is Canada's largest and among the most highly prized freshwater sport fishes (Scott and Crossman 1973). Whereas many aspects of the biology of adults are available (see Crossman and Goodchild 1978), descriptions of the development of young muskellunge and other esocids are relatively incomplete. Galat (1973) gave details of the development of the muskellunge from fertilization until hatching, and Fish (1932) described some larval stages and illustrated 12 to 15 mm specimens. Both authors used muskellunge from the Chautauqua Lake Hatchery, New York. Buynak and Mohr (1979) recently described the larvae and juveniles of muskellunge from the Susquehanna River, Pennsylvania.

The present paper serves to fill gaps in the description of the early life history of a geographical race of muskellunge (Crossman 1978) from the central region (Hourston 1952) of a Great Lakes watershed, in that it reports on the gross development of larval and early juvenile stages. Hatchery reared fish were used because natural young, which are seldom seen in nature or captured with larval fish samplers, were not available. A brief comparison between three sympatric species of esocids is given as an identification aid.

METHODS

Eggs and sperm were stripped from wild adults during their spawning run in Stony Lake, Ontario (44° 33'N; 78° 09'W) on April 27, 1981, and May 1, 1982. Fertilized eggs were transported to the Deer Lake Hatchery (Ontario Ministry

of Natural Resources) near Havelock, for subsequent culture and propagation. Water from Cordova Lake was supplied at a rate of 490 to 570 L • min^{-1} to indoor facilities and outdoor rearing ponds, which were about 0.14 ha and 1.5 m deep.

Specimens were usually collected every second day and fixed live in 10 percent buffered formalin, then transferred four to six weeks later to Davidson's B for permanent dark-storage at 25°C. Additional fish were cleared and stained using a modified method of Taylor (1967), to verify initial counts of myomeres and follow progressive ossification of the skeleton. Preserved specimens from local collections of grass pickerel, Esox americanus vermiculatus, and northern pike, E. lucius, were examined in order to compare with muskellunge some aspects of early development. Terminology for developmental phases follows Snyder (1976), except that early juveniles lacked segmentation in rays of all fins. Descriptions follow the telegraphic style (see Mayr, et al. 1953).

Morphology is described with the aid of body measurements, which were taken of the left side of each fish. Linear measurements, to 0.02 to 0.1 mm (depending on size), were taken using a dissecting microscope, equipped with an ocular micrometer and polarized light. The diameters (random axis) of eggs and oil globules were measured using a compound microscope. Measurements taken were:

Total length (TL) = anterior-most point of head to tip of caudal fin.

Standard length = anterior-most point of head to posterior extremity of notochord or hypurals.

Fork length = distance from anterior margin of head to middle of caudal fin.

Preanal length = anterior margin of head to centre of anus.

Orbit = horizontal diameter of orbital rim.

Head length = linear distance between anterior margin of head to base of pectoral fin, cleithrum, and posterior edge of operculum, as each successive structure developed.

Snout to fin = anterior margin of head to origin of specific fin.

Interorbital width = minimum dorsal width between orbital rims.

Snout length = anterior-most point of upper jaw to anterior rim of orbit.

Greatest depth and width excluded dorsal fin fold and yolk sac.

A camera lucida was used to assist in illustrating specimens, with details added free-hand. All descriptions, measurements, and sketches were of fish that had been preserved from 2 to 24 months.

Myomere counts excluded the final preanal, deltoid-shaped segment (Lippson and Moran 1974), whose exact anterior limit was often difficult to discern. The final preanal myomere is that which is transected at its ventral edge by an extended vertical line from the posterior margin of the anus; the terminal, incomplete myomere was included in the postanal count. Repeated counts of myomeres of juvenile fish were necessary because pigment obscured myosepta.

RESULTS

Diagnosis

Stony Lake muskellunge protolarvae have slender bodies, dominated by large, essentially pigment-free yolk sacs and amber yolk containing numerous oil globules. They have 41 to 42 preanal and 64 to 68 total myomeres, preanal length greater than two-thirds body length, and a dark brown, body-length hypaxial stripe.

Metalarvae and mesolarvae have a large head, and an elongate snout with projecting lower jaw. The muskellunge transforms into the juvenile stage at a size (ca. 40 mm) larger than others of the genus. Fish 30 to 60 mm are elongate both in body (preanal length 69 percent) and snout (45 to 50 percent head length).

DESCRIPTIONS

Eggs

Preserved, unfertilized eggs varied in size, colour, and in the number and size (0.04 to 0.14 mm) of oil globules, but were generally amber, slightly oval, and 2.7 mm in mean diameter (N = 350; range: 2.2 to 3.2 mm). Fertilized, one-day-old (21 degree-days) preserved eggs (N = 120) were 2.9 mm, as were seven-day-old (89 degree-days) eggs (N = 120).

Protolarvae

1. Morphology

The protolarval phase included young fish between 7.8 and 16.1 mm TL (Fig. 1 A-K), and ended when larvae acquired at least one obvious fin ray in a median fin. Muskellunge eggs in 1981 hatched after 193 degree-days at an average mid-daily temperature of 11.3°C.

Larvae (hatched) 7.8 to 8.9 mm: head arched, deflected ventrally over anterior of bulbous yolk sac (Fig. 1 A-C); mouth incomplete; paired, crescent-shaped adhesive glands between orbits and upper jaw; eyes with choroid fissure; yolk: amber, with small, oval oil globules located mostly lateroventrally near surface; median fin fold commencing dorsally at fifth or sixth myomere, continuous with ventral fin fold, which terminated high on posteroventral surface of yolk sac (Fig. 1 C); fin fold widest at caudal peduncle, anus abruptly decurved, extended to margin of ventral fin fold; pectoral fin buds present.

Length 10.5 mm (327 degree-days; Fig. 1 E-G): lower jaw extended slightly anterior to upper jaw, which reached to orbit; teeth small, sharp, conical on lower jaw; branchiostegal rays: two, incomplete. In cleared and stained larvae, first sites of ossification: upper half of cleithrum, lower margin of premaxilla, anterior margin of lower jaw, base of operculum. Dorsal fin fold origin at thirteenth myomere, width reduced, especially at caudal peduncle.

Length 14.8 mm (Fig. 1 K): swim bladder present; fin rays not elaborated; dorsal and anal pterygiophores developed; branchiostegals, two formed; yolk sac with remnants of yolk. Cleared, stained specimens indicated sites of ossification: jaws, dorsal and ventral margins of opercle, and

cleithrum; teeth evident, ossified vomerine, palatine, maxillary clearly evident; first rays evident in ventral of caudal fin.

2. Pigmentation

At hatch, large, branching melanophores at posterior of eye merged with a narrow band of pigment at gill arches (Fig. 1 A), head otherwise essentially clear; distinct band of melanophores extended hypaxially from gill arches to caudal region; ventral concentration of small spots near straight urostyle; anus and yolk sac dark brown at posterior margin.

10.5 mm: pigment increased over gill arches, sides of mouth, and hypaxially (Fig. 1 F, G) with isolated stellate melanophores on dorsum; eyes dark, silvery.

Length 14.1 mm: extensive pigmentation on sides of snout and below orbit, distal hypaxial portion of caudal peduncle.

Length 14.8 mm: small stellate melanophores formed two indistinct ventral lines anterior to anus.

3. Morphometry and Meristics

Length 7.8 to 8.9 mm: yolk sac length: 3.2 mm, yolk length: 2.8 mm, width: 2.2 mm (Fig. 1 B-D); ca. 50 oil globules, diameter: 0.1 to 0.3 mm; fin fold maximum width: 0.6 mm; body depth: 0.7 mm; pectoral fin bud length: 0.4 mm; interorbital width 45 percent head length.

Length 11.6 mm (Fig. 1 H): yolk sac length 4.0 mm, yolk length: 3.5 mm, width 1.4 mm.

Length 14.8 mm (Fig. 1 K): swim bladder evident, 2.8 mm long; yolk sac 2.7 mm long; teeth 0.06 mm; interorbital width 23 percent head length; pectoral fins 1.4 mm long; body depth: 1.4 mm.

Table 1 lists morphometric and meristic data.

Mesolarvae

1. Morphology

Larvae 16.8 to 28.9 mm were included in this phase. Length 16.8 mm: first appearance of median rays in ventral lobe of caudal fin fold; median fin fold origin at twenty-fourth myomere; swim bladder inflated; jaws articulated below centre of pupil; dorsal fin, trace of rays. Late phase (Fig. 2 B): body elongate, snout laterally pointed, dorsally broadened; urostyle slightly flexed; fin fold present; caudal fin forked.

2. Pigmentation

Progressive increase in intensity on snout, suborbital and postorbital areas, gill arches, posterior margin of anus, vertical lateral patch at caudal peduncle, melanophores prominent lateroventrally on posterior two-thirds of body, outlining myomeres; stellate melanophores scattered on most of epaxial region, contracted melanophores on dorsum, anterior margin of anus; unpigmented areas: cheeks, orbit to operculum, lateral line, base of dorsal, anal fin (Fig. 2 A, B).

3. Morphometry and Meristics

Length 16.8 mm: pterygiophores, dorsal 8, anal 10; pectoral fin length 1.6 mm; pelvic fin buds present (56 percent TL from tip of snout). Length 19.4 mm: dentary teeth marginal, 24 (12 each side), palatine teeth: 18 (9 each side), vomerine teeth numerous, pharyngobranchial teeth minute.

Length 21 mm: branchiostegal rays half adult complement, vertebrae 65, cartilaginous; anal fin rays typically 10, dorsal fin rays typically 12, caudal fin rays 6 (weakly developed).

Length 28 mm: pectoral, pelvic fins 1.7 mm, 0.7 mm in length, respectively; anal fin typically 12 rays; snout to dorsal fin length 73 percent TL; interorbital width ca. 20 percent head length.

Table 1 lists morphometric and meristic data.

Metalarvae

1. Morphology

Length 29.1 mm: median fin rays, full adult complement; preanal fin fold present; head, main site of morphological change mid to late phase (Fig. 2 C, D); lower jaw projected; interorbital area, snout slightly concave; snout laterally pointed, dorsally broadened.

Length ca. 41 mm: entire fin fold absorbed; fins incomplete segmentation; orbits high on dorsal ridge.

2. Pigmentation

Progression throughout metalarval phase from individual lateral body melanophores to vermiculation; dorsal fin base, caudal peduncle with concentration of small and large stellate melanophores; characteristic dark brown lateral stripe from snout, through orbit, thence posteriorly along hypaxial (but not ventral) region of body to caudal fin. Length ca. 37 mm: posterior of operculum edged with small, dark melanophores.

3. Morphometry and Meristics

Length 29.1 mm: pelvic fin rays 6 to 7; pectoral fin rays not obvious, snout length: 45 percent head length; orbit 20 percent head length; interorbital width: 18 percent head length; dorsal fin rays 17 to 18, anal fin rays 15 to 17, caudal fin rays 19. Late metalarvae: pelvic fin rays 9 to 10, pectoral

fin rays 10 to 12, weakly developed. Preanal myomeres 39 to 41, modally 40, postanal myomeres 20 to 22, modally 20.

Table 1 lists morphometric data for 29.1 to 43.8 mm metalarvae.

Juveniles

1. Morphology

Increased elongation of body, relative reduction of head length, snout laterally pointed, dorsally flattened as development proceeds (Fig. 2 E, F); antero-hyals 8, postero-hyals 9, each side; maxilla extended to below single nostril; pectoral fins last to develop full complement of rays, ventral rays last to form. Length 53 mm: first site of squamation (caudal peduncle), cycloid scales, extended anteriorly along lateral line to mid-body. Length 62.6 mm: scales small, on lateral line, body patch near cleithrum.

2. Pigmentation

Head (Fig. 2 E): lateral band of minute melanophores extending from lower jaw to below nostrils, connecting with heavy triangular patch at anterior and posterior margin of orbit, pigment faded at dorsal margin of operculum; body: dorsal, hypaxial variegation, otherwise, cream-coloured, notably venter; fins: anal, pelvic, unpigmented (small juveniles), dorsal fin rays edged with small melanophores, caudal fin heavily pigmented, except margins of lobes; pectoral fins with large stellate melanophores at base, small melanophores along edge of inferior and exterior rays. Pigment in older juveniles about twice as intense epaxially as hypaxially.

3. Morphometry and Meristics

Supraorbital and infraorbital sensory pores 4 each, submandibular pores 12; teeth, dentary 0.2 to 0.6 mm to long; scales, ca. 153.

Length 40 mm: snout length ca. 47 percent head length; segmented fin ray mean count: dorsal 17, anal 16, caudal 19; fork length 95 percent TL.

Length 60 mm: snout length 50 percent head length; orbit 15 percent head length. Preanal myomeres 38 to 40 (modally 39), postanal myomeres 19 to 24 (modally 23), total 58 to 63 (modally 63).

Morphometric data for juveniles 40.3 to 67.9 mm are given in Table 1.

DISCUSSION

In some aspects of early development, Stony Lake muskellunge appear to be in advance of populations described by Fish (1932), Buynak and Mohr (1979), Applegate (1982), and those summarized by Fuiman (1982). For example, at 10.5 mm, Stony Lake protolarvae had an open mouth, and at 14.5 to 14.8 mm, a filled swim bladder; these events occurred in Pennsylvania fish at 11.4 mm (Buynak and Mohr 1979). In Stony Lake muskellunge, the onset of hypural formation was at 13.6 mm, pelvic buds first appeared at 16.8 mm, the lower jaw extended beyond the upper jaw at ca. 14.1 mm, and cannibalism was first observed at 20 mm. In other races, these developments occurred at 16.0 mm (Fuiman 1982), 24.9 mm, and 25.7 mm (Buynak and Mohr 1979) and ca. 33 mm (Applegate 1982). Fish (1932) noted in 33.8 mm larvae extension of the maxilla almost to the posterior margin of the orbit, whereas the maxilla of Stony Lake fish extended to the anterior margin of the orbit. This suggests a

difference in gape, and could possibly affect feeding ability or selection of prey of appropriate size during periods of critical food supply. Thus, it is likely that if ever races were to intermingle, asynchrony in development and growth may prove critical for survival. These racial differences are slight and subtle, but species differences are more obvious and definite.

Comparison of the parallel early development of three sympatric esocids, muskellunge, northern pike, and grass pickerel, revealed several differences useful for taxonomic separation. Whereas details in the literature of egg sizes are various, and differ according to whether or not the eggs are fertilized, and the type of preservative used, our measurements indicate the mean size of preserved (in Davidson's B) fertilized eggs of muskellunge were 2.9 mm, and of northern pike, 2.8 mm. Although Fuiman (1982) reported northern pike eggs as smaller than those of grass pickerel, we found the reverse, i.e., grass pickerel eggs were smaller (2.1 mm), than northern pike eggs.

Kleinhart and Mraz (1966) separated grass pickerel and northern pike at lengths less than 12 mm on the basis of hatch size and eye colour, but found these species difficult to separate in the size range 12 to 20 mm. However, grass pickerel and northern pike differ considerably in myomere number (Table 2), which effectively separates them. At lengths exceeding 20 mm, northern pike are spotted laterally (Kleinhart and Mraz 1966), but young grass pickerel possess a clear stripe that extends from snout to the caudal fin. Muskellunge also have a clear body-length stripe, with lateral, diagonal bars that accentuate the myomeres from anus to caudal peduncle.

In juvenile grass pickerel, scales are first evident at 50 mm (Lippson and Moran 1974); in northern pike, they appear at 30.5 to 32 mm (Franklin and Smith 1960), and in muskellunge at 45 mm. Young fishes of the three species can be further separated on the basis of diagnostic characters summarized by Fuiman (1982), and developmental events listed in Table 2.

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Table 1. Mean morphometric and modal meristic data for Esox masquinongy larvae and early juveniles, grouped by 1 and 2 mm intervals of total length; N = number of fish; range of total lengths and myomeres in parentheses.

	LENGTH					MYOMERES		
N	TOTAL	STANDARD	PREANAL*	HEAD	ORBIT	PREANAL	POSTANAL	TOTAL
A) Protolarvae								
1	7.8	7.7	5.7	1.2	0.5	42	24	66
16	8.6	8.5	6.0	1.4	0.5	42	25	67
	(8.2-8.9)	(8.1-8.8)	(5.2-6.1)	(1.2-1.5)	(0.5-0.6)	(40-43)	(23-26)	(65-68)
20	9.4	9.3	6.4	1.5	0.6	41	25	66
	(9.0-9.9)	(8.9-9.7)	(6.1-6.8)	(1.4-1.6)	(0.5-0.7)	(40-43)	(23-26)	(65-68)
19	10.6	10.4	7.2	1.7	0.6	42	25	67
	(10.0-10.9)	(9.9-10.7)	(6.6-7.6)	(1.6-1.8)	(0.6-0.7)	(40-44)	(22-26)	(66-69)
16	11.5	11.3	7.8	2.0	0.7	41	25	66
	(11.0-11.9)	(10.8-11.7)	(7.5-8.2)	(1.8-2.2)	(0.6-0.8)	(40-44)	(24-26)	(65-68)
20	12.5	12.3	8.5	2.3	0.8	42	23	65
	(12.0-12.9)	(11.8-12.8)	(8.0-9.0)	(2.0-2.6)	(0.7-1.0)	(40-44)	(22-25)	(63-68)
31	13.4	13.2	9.0	2.7	0.9	40	23	63
	(13.0-13.9)	(12.7-13.8)	(8.7-9.6)	(2.4-3.1)	(0.8-1.0)	(40-43)	(21-25)	(62-67)
16	14.4	14.2	9.8	3.3	1.0	40	25	65
	(14.1-14.7)	(13.9-14.5)	(9.5-10.0)	(2.8-3.6)	(0.9-1.1)	(40-44)	(20-25)	(61-69)
10	15.4	15.2	10.5	3.7	1.1	41	22	63
	(15.0-15.9)	(14.8-15.7)	(10.1-11.0)	(3.3-4.2)	(1.0-1.2)	(40-43)	(20-25)	(62-67)
B) Mesolarvae								
1	16.8	16.4	11.5	4.5	1.2	40	21	61
6	17.5	17.3	12.4	4.8	1.2	41	22	63
	(17.4-17.8)	(17.0-17.6)	(12.1-12.7)	(4.6-5.0)	(1.2-1.3)	(40-42)	(20-25)	(61-66)
5	18.6	18.3	13.3	5.3	1.3	40	22	62
	(18.1-18.8)	(17.9-18.6)	(12.9-13.7)	(4.7-5.6)	(1.2-1.4)	(40-42)	(20-22)	(61-62)
6	19.6	19.3	13.9	5.6	1.4	41	22	63
	(19.1-19.9)	(18.6-19.7)	(13.3-14.3)	(5.1-6.0)	(1.3-1.4)	(41-42)	(21-23)	(62-66)
5	20.6	20.2	14.8	6.0	1.4	41	22	63
	(20.1-20.8)	(19.9-20.5)	(14.6-14.9)	(5.8-6.2)	(1.4-1.5)	(40-41)	(20-23)	(61-63)
6	21.6	21.3	15.6	6.5	1.5	41	21	62
	(21.1-21.8)	(20.8-21.5)	(15.1-16.0)	(6.1-7.1)	(1.4-1.6)	(40-41)	(21-23)	(61-66)
7	22.4	22.2	16.1	6.5	1.5	41	22	63
	(22.1-22.7)	(21.7-22.6)	(15.6-16.6)	(6.0-6.8)	(1.4-1.6)	(40-42)	(21-23)	(62-64)
10	23.6	23.4	17.1	7.4	1.6	41	20	61
	(23.1-23.9)	(22.9-23.7)	(16.3-17.8)	(6.9-7.9)	(1.5-1.7)	(40-42)	(20-22)	(61-62)
3	24.6	24.4	17.8	7.7	1.7	40	21	61
	(24.4-24.9)	(24.2-24.7)	(17.6-17.9)	(7.6-7.8)	(1.7)	(40-41)	(20-21)	(60-62)
4	25.6	25.2	18.5	8.1	1.7	41	21	62
	(25.3-25.9)	(24.9-25.6)	(17.8-19.1)	(8.0-8.4)	(1.7-1.8)	(41)	(21)	(62)
3	26.7	25.7	19.1	8.4	1.8	41	22	63
	(26.4-26.9)	(24.9-26.4)	(18.6-19.3)	(8.1-8.6)	(1.7-1.9)	(41)	(21-22)	(62-63)
2	27.4	26.3	19.8	8.4	1.7	41	21	62
	(27.1-27.7)	(25.9-26.6)	(19.4-20.1)	(8.3-8.5)	(1.7)	(40-41)	(20-21)	(60-62)
2	28.7	27.3	20.5	9.0	1.8	41	21	62
	(28.4-28.9)	(26.7-27.9)	(20.1-20.8)	(8.7-9.2)	(1.7-1.8)	(40-41)	(20-21)	(60-63)

* Measurements to 23.6 mm TL taken from snout to end of notochord; thereafter, to hypurals.

Table 1: (cont'd)

N	LENGTH TOTAL	STANDARD	PREANAL	HEAD	ORBIT
C) Metalarvae					
8	29.8	28.0	21.1	9.7	1.9
	(29.1-30.7)	(26.9-28.7)	(20.3-21.9)	(9.0-10.1)	(1.8-2.0)
5	32.1	29.7	22.7	10.4	2.0
	(31.5-32.5)	(29.1-30.2)	(22.4-23.2)	(10.1-10.8)	(1.9-2.2)
3	34.4	31.8	24.4	10.9	2.1
	(33.5-34.9)	(31.0-32.4)	(24.1-24.6)	(10.6-11.1)	(2.1-2.2)
2	36.8	33.3	26.7	13.3	2.3
	(36.7-36.9)	(33.2-33.4)	(25.6-27.8)	(12.9-13.6)	(2.3)
3	38.0	35.0	26.8	12.5	2.2
	(37.2-38.8)	(34.4-35.5)	(26.4-27.2)	(12.1-13.3)	(2.2-2.3)
1	39.5	36.9	28.2	13.3	2.3
D) Juveniles					
4	40.9	37.3	28.3	13.7	2.4
	(40.2-41.2)	(36.7-39.2)	(28.1-28.6)	(13.3-14.1)	(2.3-2.5)
5	43.1	39.3	29.8	14.4	2.4
	(42.7-43.8)	(38.7-40.0)	(29.1-30.5)	(14.1-14.9)	(2.2-2.6)
5	44.9	41.2	31.1	14.9	2.5
	(44.3-45.5)	(40.3-42.8)	(30.7-31.7)	(14.6-15.1)	(2.4-2.5)
7	46.9	42.9	32.3	15.4	2.6
	(46.1-47.6)	(42.0-44.3)	(31.7-33.0)	(14.9-15.6)	(2.5-2.7)
5	49.1	44.1	33.7	16.2	2.6
	(48.3-49.8)	(43.3-44.8)	(32.5-38.3)	(15.3-17.9)	(2.5-2.8)
4	50.8	46.0	35.1	16.7	2.7
	(50.3-51.1)	(45.5-46.5)	(34.2-35.9)	(16.4-16.8)	(2.7-2.8)
1	53.0	47.6	36.0	17.1	2.8
1	54.8	49.5	37.8	18.0	2.9
4	56.6	51.1	38.6	18.2	2.9
	(56.3-57.1)	(50.5-51.6)	(38.2-39.0)	(17.9-18.6)	(2.7-3.0)
1	58.4	52.6	39.3	18.8	3.0
1	61.3	54.2	41.2	19.6	3.2
4	62.8	55.8	42.4	20.1	3.1
	(62.3-63.1)	(54.5-56.6)	(41.4-43.2)	(19.4-20.4)	(3.0-3.2)
1	65.4	59.3	45.2	20.9	3.2
2	67.8	59.9	45.6	21.6	3.3
	(67.6-67.9)	(59.8-59.9)	(45.3-45.8)	(21.1-22.1)	(3.3)

Table 2. Some comparative characteristics and events in the early development of three species of sympatric esocids. Total lengths, in millimeters.

Event or characteristic	Species		
	Grass pickerel	Northern pike	Muskellunge
Hatch length	5.0-6.0 (d)	8.3 (b) 7-9 (l) 6.5-8.0 (c)	7-9 (b) 7.8-8.9 (a)
Yolk sac pigmentation	peppered, dark spots (a)	stellates, spots (a)	scant (a)
Oil globules	numerous, minute (a)	sub-surface clusters (k)	large and small, numerous (a)
Cleithrum formed	8-9 (a)	12-12.5 (a)	12.6 (a)
Dorsal and ventral finfold equal length	ca. 12.0 (a)	ca. 17.0 (a)	ca. 14.0 (a)
Choroid fissure closed	16.0 (a)	20.0 (a)	24.0 (a)
Pelvic buds formed	11.6 (f)	15 (b) 13 (g)	16.8 (a) 24.9 (b)
Fin rays formed	20 (h)	38.6 (b)	29.1(a) 39 (b)
Sub-mandibular pores (number)	8 (i)	9-11 (i)	12-20 (j)
Finfold absorbed	22 (f)	26-35 (e)	41 (a)
Myomeres			
preanal	31 (f)	41-46 (b)	46 (e), 44-48 (b)
postanal	15+ (f)	20-24 (b)	26 (e), 17-24 (b)
total	46 (f)	61-68 (b)	64-70 (b)

(a) Authors (this study); (b) Buynak and Mohr (1979); (c) Franklin and Smith (1963); (d) Kleinhart and Mraz (1966); (e) Fish (1932); (f) Mansueti and Hardy (1967); (g) Embody (1910); (h) Wang and Kernehan (1979); (i) Crossman (1962); (j) Scott and Crossman (1973); (k) Kennedy (1969); (l) Fuiman (1982).

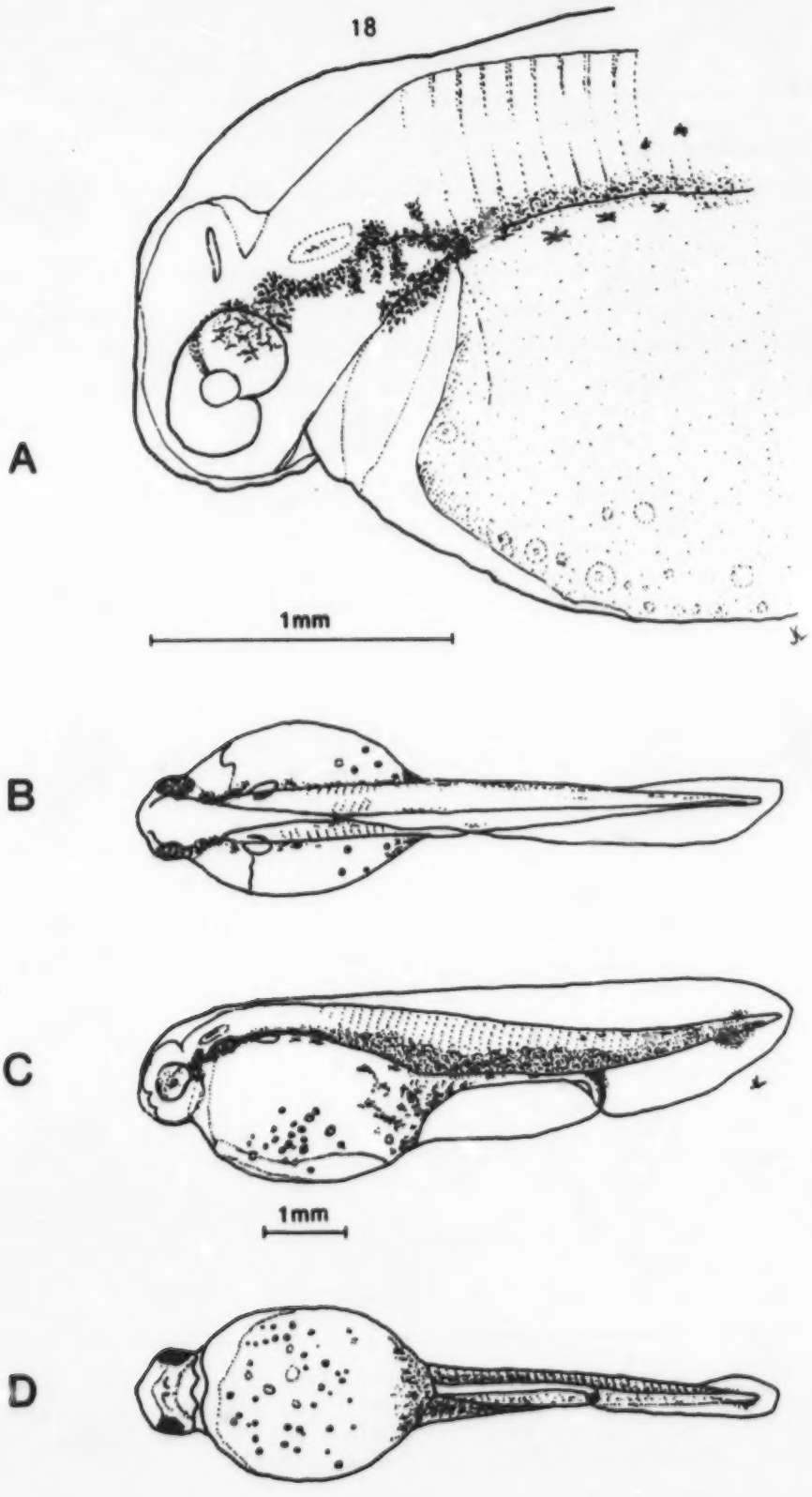

Figure 1. (i) Esox masquinongy **protolarva, 8.5 mm (A - head, B - dorsal, C - lateral, D - ventral view)**

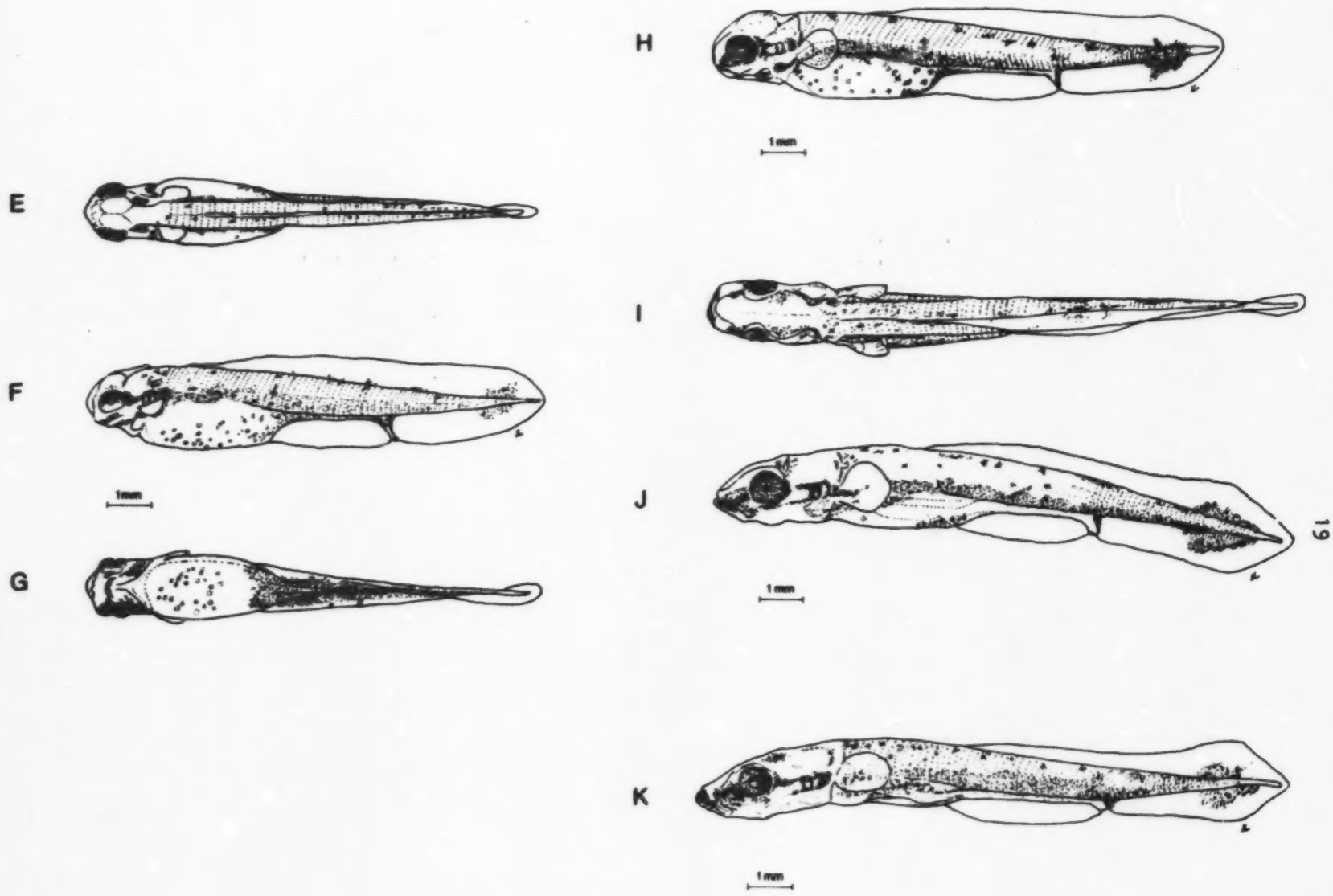

Figure 1. (ii) Esox masquinongy protolarvae, 10.5 mm (E - dorsal, F - lateral, G - ventral view); 11.6 mm (H) - lateral view; 14.1 mm (I - dorsal, J - lateral view) and 14.8 mm (K) - lateral view in total length.

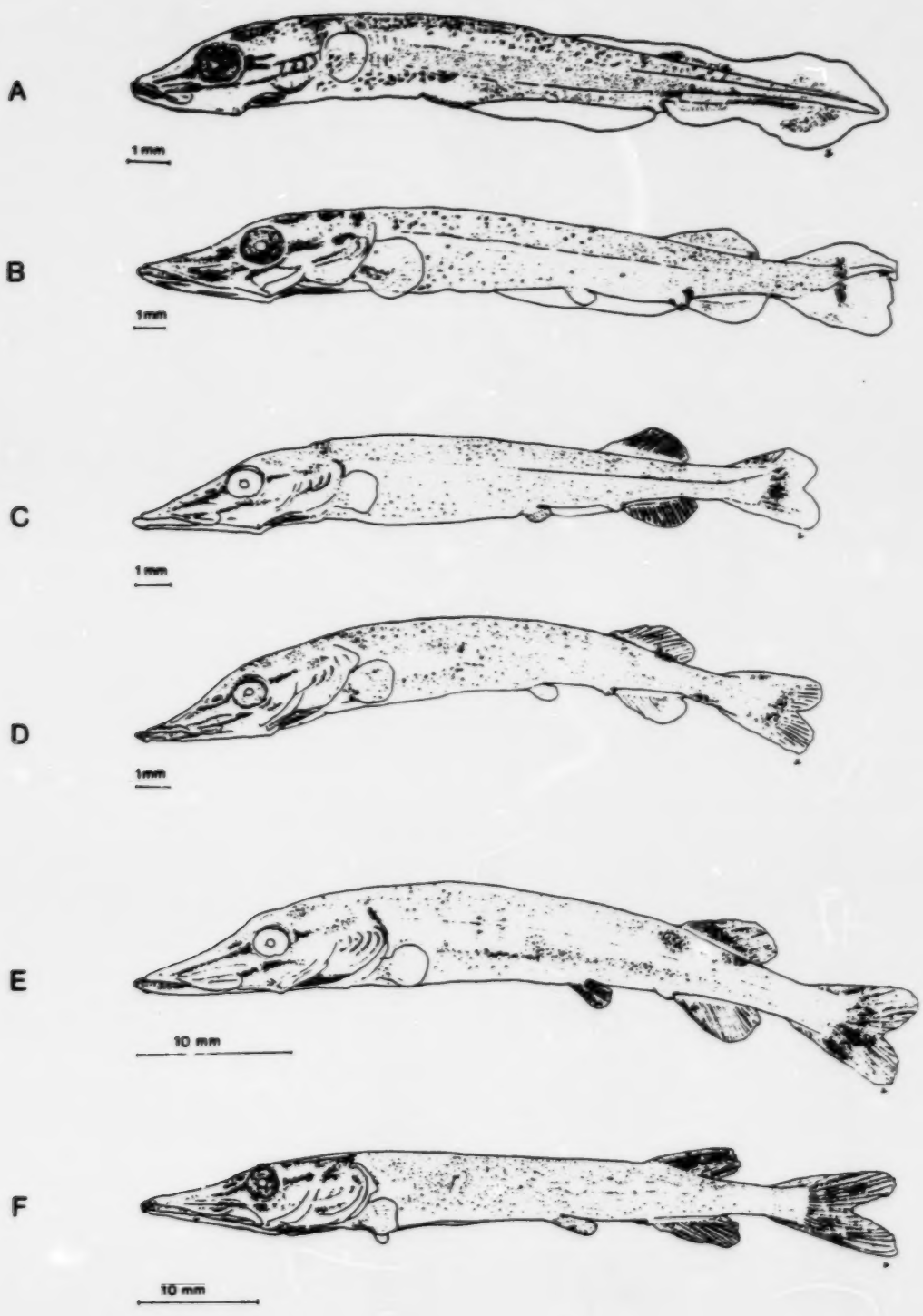

Figure 2. Esox masquinongy mesolarvae, 18.3 mm (A) and 25.1 mm (B); metalarvae, 37.5 mm (C) and 40.3 mm (D); early juveniles, 51.3 mm (E) and 63.0 mm (F) in total length.

POOR

QUALITY

ORIGINAL